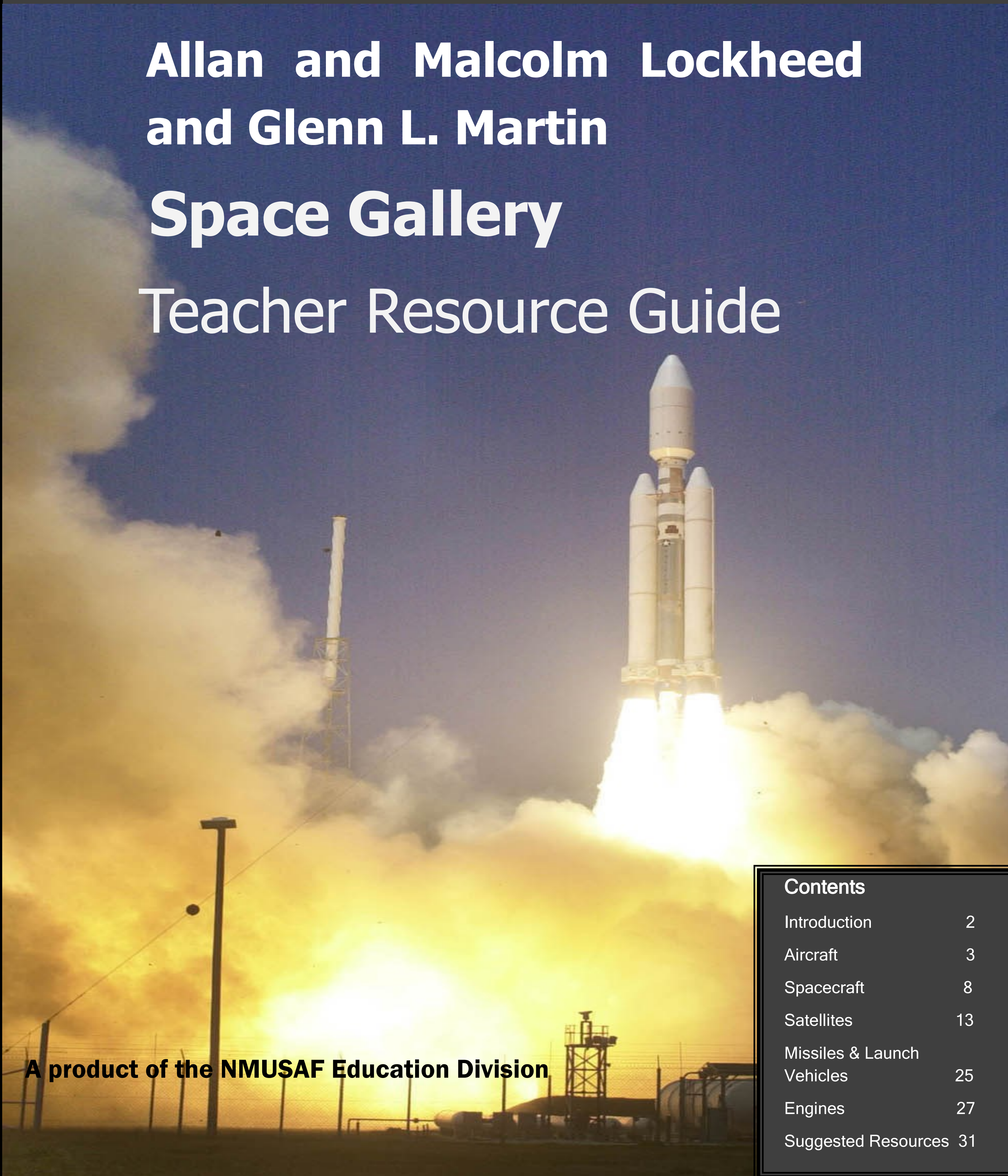
NATIONAL MUSEUM
OF THE UNITED STATES AIR FORCE™

Allan and Malcolm Lockheed and Glenn L. Martin

Space Gallery

Teacher Resource Guide



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An Introduction

Since the beginning of the space age after World War II, the U.S. Air Force has provided technical expertise and leadership in developing and using space technology to preserve national security.

The U.S. Air Force has been a leader in missiles, astronautics, and orbital technology. It has developed, launched, and controlled satellites of all kinds; maintained the nation's nuclear deterrent; and provided skilled Airmen for National Aeronautics and Space Administration's (NASA) astronaut corps. Air Force expertise in weather, navigation, reconnaissance, communications, aerospace medicine, missile and rocket maintenance and launch, and many other fields, continues to enhance American air, space, and cyberspace power. This Space Gallery highlights the U.S. Air Force's many achievements on the "High Frontier."

Allan and Malcolm Lockheed, born with the last name "Loughead," were determined and visionary aviation pioneers who overcame numerous challenges and setbacks to found the organization bearing their name. This company grew into one of the U.S. Air Force's most important producers of military aircraft, rockets, and numerous other systems that helped move America and the Air Force into air, space, and cyberspace.

Glenn Martin helped lead the way in developing the close relationship needed between the military services and American industry. Martin built many of the most important military aircraft from the 1920s to the 1940s. The company he founded continued the close relationship by producing the Titan I, Titan II, and Peacekeeper missiles for the U.S. Air Force's land-based strategic nuclear deterrent.

Aircraft

North American X-15A-2 Hypersonic Research Aircraft

The X-15 is a famous and significant part of aviation history. Its purpose was to fly high and fast, testing the machine and subjecting pilots to conditions that future astronauts would face. It made the first manned flights to the edges of space and was the world's first piloted aircraft to reach hypersonic speeds, or more than five times the speed of sound. The X-15 was an important tool for developing spaceflight in the 1960s, and pilots flying above 50 miles altitude in the X-15 earned astronaut wings.

TECHNICAL NOTES:
Crew: One

Engine: Reaction Motors XLR-99 of 50,000+ lbs. thrust

Maximum speed: 4,520 mph (Mach 6.7)

Ceiling: 354,200 ft. (67 miles)

Three X-15s were built, and they made 199 flights between 1959-1968. The program was a joint US Air Force/Navy/NASA project, and four of its twelve pilots were US Air Force officers. One pilot, USAF Maj Michael J. Adams, died in an X-15 crash in 1967. Another X-15 pilot, Neil Armstrong, later became the first man to walk on the moon.

Like other rocket planes, the X-15 was launched in midair from a B-52 "mothership" at about 45,000 feet. Once its powerful rocket ignited, the X-15 streaked upward to the limits of the atmosphere, then glided unpowered to land on a dry lake bed. Typical flights lasted about 10 minutes.

This aircraft is the second of the three X-15s. North American modified it for even greater speed, adding the large orange and white propellant tanks and lengthening the fuselage about 18 inches. This was the fastest X-15, reaching Mach 6.7 in October 1967. It was delivered to the Museum in 1969.

Martin X-24A Lifting Body

This aircraft represents the Martin (now Lockheed Martin) X-24A, which the US Air Force and NASA flew to study flight characteristics and maneuverability of "lifting bodies." A lifting body is a fixed-wing air or spacecraft—such as the Space Shuttle—in which the body itself produces lift. The X-24A paved the way for the Space Shuttle by showing that a lifting body could glide through the atmosphere and land on Earth like an airplane.

X-24 flights focused on the last stage of re-entry from space, with pilots flying lifting bodies at speeds of around 1,000 mph and altitudes of around 70,000 feet. Smaller unmanned vehicles with similar shapes conducted tests at higher speeds and altitudes.

The X-24A made twelve gliding tests in 1969 and 1970, dropped from a NASA modified B-52. Twenty-eight powered flights followed in 1970 and 1971. Flights typically lasted under eight minutes, with a 2.5 minute rocket burn followed by a 5 minute glide to landing. One of the last X-24A flights simulated a space shuttle landing approach from about 71,400 feet, and another featured the aircraft reaching Mach 1.6, its fastest speed.

TECHNICAL NOTES:
Crew: One

Engines: One Reaction Motors XLR-11 rocket of 8,000 lbs. thrust; two Bell LLRV optional landing rockets of 400 lbs. thrust each

Maximum speed: 1,218 mph (Mach 1.6)

Ceiling: 71,407 ft.

The aircraft on display was originally the jet-powered Martin SV-5J, a derivative of the X-24A built for flight training. It was never flown. For display purposes, the SV-5J has been modified to represent the X-24A. Martin donated it to the Museum in 1971. In 1973, the actual X-24A was converted into the X-24B on display.

Martin X-24B Lifting Body

The X-24B aircraft showed that a "lifting body" could glide through the atmosphere and make a precise landing on a runway like an airplane. A lifting body is a fixed-wing air or spacecraft in which the body itself produces lift. X-24 studies supported Space Shuttle development in the early 1970s. The US Air Force, NASA, and Martin Aircraft (now Lockheed Martin) heavily modified the X-24A to make a higher-performing vehicle, the X-24B.

The X-24B's flat bottom and long nose added surface area to improve gliding qualities, increasing range and maneuverability. It flew thirty-six times between 1973 and 1975, making twelve gliding-only flights and twenty-four powered flights with gliding landings. In all its flights, a NASA modified B-52 "mothership" launched the X-24B at 45,000 feet.

In powered flights, a rocket engine accelerated the X-24B to more than 1,000 mph as it climbed to altitudes around 60,000–70,000 feet. The X-24B then made steep unpowered gliding landings like the future

Space Shuttle. Highlights of the X-24B research program included two precise landings made on a concrete runway at Edwards AFB, California (other flights landed on nearby dry lake beds). This ability to glide to a landing at a specific spot was an important step toward later Space Shuttle operations. The X-24B was the la last joint USAF/NASA rocket-powered air-launched research aircraft.

TECHNICAL NOTES:
Crew: One

Engines: One Reaction Motors XLR-11 rocket of 9,800 lbs. thrust; two Bell LLRV optional landing rockets of 500 lbs. thrust each

Maximum speed: 1,164 mph (Mach 1.76)

Ceiling: 74,100 ft.

Boeing X-40A

The unmanned, unpowered Boeing X-40A was the first-phase flight test vehicle for the US Air Force's Space Maneuver Vehicle program that began in the late 1990s. The program aimed to develop small, reusable, highly maneuverable spacecraft for deploying satellites and conducting surveillance and logistics missions.

This test aircraft is a 90 percent scale version of what would later be designated the X-37B space plane. The Boeing Company, in partnership with the Air Force Research Laboratory, built the X-40A at Boeing's Phantom Works facility at Seal Beach, California.

On August 11, 1998, the X-40A made its first successful flight at Holloman AFB, New Mexico. A helicopter lifted it to about 10,000 feet and released it. The X-40A then made an unpowered flight demonstrating guidance, navigation, and control capabilities.

Following that flight, the USAF loaned the X-40A to the National Aeronautics and Space Administration (NASA) to test X-37 aerodynamics, guidance, and other systems. After captive-carry flights to practice release procedures and test equipment, the X-40A made its first NASA flight on March 28, 2001. Released at at 15,000 feet by a helicopter, the X-40A flew itself, guided by onboard systems, to a gentle landing at Edwards AFB, California. The X-40A made a total of seven successful flights in support of the X-37 program. This aircraft came to the Museum in 2008.

TECHNICAL NOTES:

Length: 22 ft.

Span: 12 ft.

Weight: 2,600 lbs.

Fairchild C-119J Flying Boxcar Satellite Catcher

This C-119J Flying Boxcar made the world's first mid-air recovery of an object returning from space. In August 1960, it caught the Discoverer XIV satellite using recovery gear lowered from the open rear door. This mechanism snagged the satellite's parachute, and a winch slowly reeled the film capsule into the aircraft. "Satellite catching" became an important and regular US Air Force operation to recover secret reconnaissance satellite film.

The C-119 Flying Boxcar was developed shortly after World War II to carry heavy loads of cargo, paratroopers, or medical patients. Its wide rear doors and a fuselage parallel to the ground made it easy to load and unload. It first flew in 1947.

While the J model was specially developed to catch satellite film recovery vehicles, Flying Boxcars also played an important role in the Korean War carrying troops and supplies. The most important airlift mission in Korea came in the bitter winter of 1950 when USAF C-119Bs airdropped bridge sections to US troops trapped by communist forces at the Chosin Reservoir. The sections replaced a destroyed bridge across a deep chasm, allowing thousands of Soldiers and Marines to escape. Flying Boxcars also served in the Southeast Asia War as gunships supporting ground forces.

TECHNICAL NOTES:
Crew: 5

Maximum speed: 290 mph

Range: About 1,827 miles

Payload: 62 fully equipped troops or 30,000 lbs. of cargo

Ceiling: 29,670 ft.

Engines: Two Wright R3350-89s of 3,500 hp each

Spacecraft

McDonnell Mercury Spacecraft

Project Mercury was the first American human spaceflight program. Its goals were to put astronauts into orbit around the Earth, to find out if they could survive and work in space, and recover the crewmen and spacecraft safely. Between 1961 and 1963, six successful flights proved Americans could fly in space.

Mercury flights lasted from 15 minutes to 34 hours, with most lasting less than 9 hours. There was very little room for the single astronaut to move in the spacecraft, but not much was required. The pilot needed to move only his arms and head, and never left the spacecraft during flight.

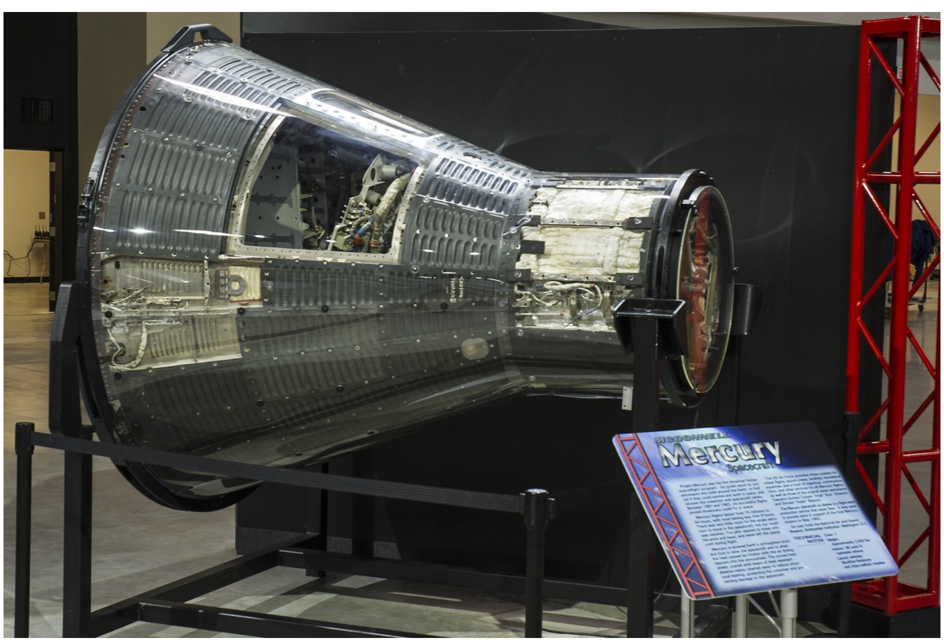
Mercury re-entered Earth’s atmosphere blunt end first to slow the spacecraft and to shed the heat caused by friction with the air during descent into the atmosphere. The curved heat shield, coated with layers of heat resistant ablative resins, charred away to reduce structural heating, protecting the crewman and preventing damage to the spacecraft.

The US Air Force provided Atlas rockets for orbital flights, launch crews, facilities, biomedical expertise, and a host of logistical, communications, and other services for all Mercury flights, as well as three of the original seven astronauts: Captains Gordon Cooper, Virgil “Gus” Grissom, and Donald “Deke” Slayton.

Standing beside a Convair F106-B aircraft in a January 1961 photograph are the nation's Project Mercury astronauts. Left to right, are M. Scott Carpenter, L. Gordon Cooper Jr., John H. Glenn Jr., Virgil I. "Gus" Grissom, Walter M. Schirra Jr., Alan B. Shepard Jr., and Donald K. "Deke" Slayton. Credits: NASA

The Mercury spacecraft on display is a flight-rated production vehicle that never flew. It was used to provide parts in support of the final Mercury mission in May 1963.

On loan from the National Air and Space Museum, Smithsonian Institution, Washington, D.C.



TECHNICAL NOTES:
Crew: 1
Weight: Approximately 2,500 lbs.
Interior: 36 cubic ft. habitable vol-ume
Launch vehicles: Modified Redstone and Atlas ballistic missiles

McDonnell Gemini B Manned Orbiting Laboratory Spacecraft

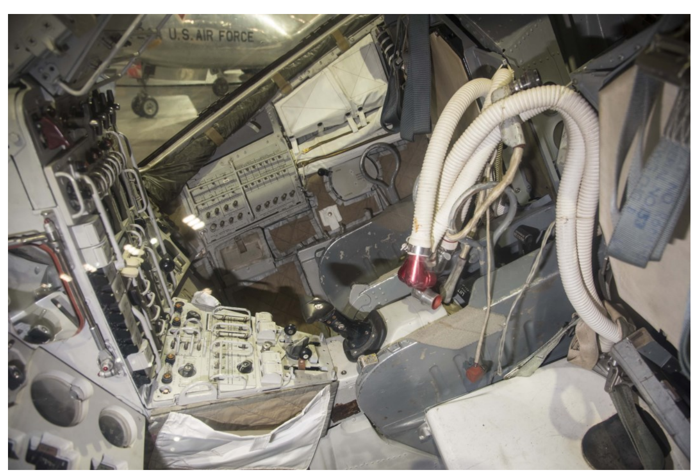
This spacecraft was built for the US Air Force's Manned Orbiting Laboratory (MOL) program, a top-secret effort to take extremely detailed reconnaissance photographs of Cold War adversaries' territory from space. The MOL program planned to use astronauts to operate cameras and evaluate the usefulness of humans in space. Gemini B was a modified version of the 2-man Gemini spacecraft that carried NASA astronauts into orbit on ten flights during 1965-66.

Gemini B looks very similar to other Gemini vehicles, but it has important differences. The easiest to see is the circular hatch leading from the crew compartment through the heat shield in the rear of the vehicle. This hatch led to a tunnel connecting the craft with the 19-foot-long Manned Orbiting Laboratory module where the crewmen would live and control reconnaissance cameras. MOL missions were to last up to 30 days. The crew would use the Gemini B vehicle only for launch and re-entry.

MOL missions were to be launched from Vandenberg AFB, California, into orbits over the north and south poles. These polar orbits ensured the best photo coverage of the Soviet Union, China, and other locations.

The MOL program began in 1963 but was canceled in 1969 for budgetary and political reasons before any manned missions were launched. Seventeen military pilots—thirteen of them USAF Airmen—trained to be MOL crewmen.

On loan from the National Air and Space Museum, Smithsonian Institution, Washington, D.C.



TECHNICAL NOTES:
Crew: 2
Weight: Approximately 6,000 lbs.
Interior: Approximately **90** cubic ft.
Launch vehicles: Titan IIIM

North American Rockwell* Apollo 15 Command Module *Endeavour

Apollo 15 was the fourth successful moon landing mission and the only Apollo mission with an all-US Air Force crew. Colonel David R. Scott, Lt Col James B. Irwin, and Maj Alfred M. Worden flew this spacecraft, named *Endeavour*, to the moon in July 1971. The command module is named after the ship that carried Capt James Cook on his famous 18th century scientific voyage.

Apollo 15 focused mainly on lunar science, and was the first mission to use a lunar rover vehicle. The crew spent four days traveling to the moon, then Scott and Irwin landed the lunar module *Falcon* on the moon's surface. They spent 67 hours exploring and setting up scientific experiments. Worden remained in orbit aboard *Endeavour* conducting experiments and photographing the moon. Just over 12 days after launch, the crew returned safely, splashing down in the Pacific Ocean near Hawaii.

Project Apollo's main goal was to land astronauts on the moon and return them safely to Earth. Beating the Soviets to the moon in the "space race" of the 1960s was an important part of the Cold War competition between the US and the Soviet Union for prestige and world leadership in science and technology. The US won the moon race when Apollo 11 landed on the moon and returned to Earth in July 1969. Apollo achieved six lunar landings through 1972, and twelve astronauts walked on the moon. Of the 29 astronauts who flew Apollo missions, 14 were Air Force officers or had Air Force experience.

On loan from the National Air and Space Museum, Smithsonian Institution, Washington, D.C.

TECHNICAL NOTES:
Crew: 3
Weight: 12,831 lbs. at launch
Interior: 210 cubic ft. (about the size of a minivan)

These three astronauts have been named by the National Aeronautics and Space Administration (NASA) as the prime crew men of the Apollo 15 lunar landing mission. They are, left to right, James B. Irwin, lunar module pilot; David R. Scott, commander; and Alfred M. Worden, command module pilot. Credits: NASA

Space Shuttle Crew Compartment Trainer

The Space Shuttle Crew Compartment Trainer 1 (CCT-1) is one of three shuttle mockups used to train shuttle astronauts. In CCT-1, crewmembers learned and practiced many procedures for space missions from the first shuttle mission in 1981 to the end of the program in 2011. Rockwell International Corporation built CCT-1, modeled on the space shuttle *Columbia*, in 1979. More than 300 astronauts learned and refined their skills in this simulator.

Crewmembers used the CCT to practice on-orbit tasks, train for emergency escapes, and evaluate engineering issues. On the CCT's top level, a very accurate flight deck has seating for the commander, pilot, and, during launch and re-entry, two mission specialist astronauts. The flight deck has all the same instruments, panels, lights, seats, and switches found in a real orbiter. The instruments are non-functional, but they look and feel like real ones. A closed-circuit TV system also aided training.

The lower part, or mid-deck, replicates the main space shuttle living and working area. It features sleep stations, a galley, storage lockers, a bathroom, equipment stowage racks, and a side hatch. Escape equipment such as an inflatable slide and an extendable pole used for parachuting away from the shuttle helped crews learn emergency skills. Three mission specialists and one instructor could sit in the CCT’s mid-deck. A treadmill and biomedical sensors could also be installed.

The CCT is the front part of this exhibit. The rest of the structure is a mock-up payload bay and tail section built to represent the size of the shuttle and provide exhibit space. The CCT arrived at the Museum in 2012.

Satellites

During the Cold War, the U.S. relied on photo reconnaissance satellites to track adversaries' weapons development, especially in the Soviet Union and China. From the early 1960s to mid-1980s, photography from space was often the only way to get critical data about nuclear threats.

The National Reconnaissance Office (NRO), Department of Defense (DoD), U.S. Air Force, Central Intelligence Agency (CIA), and industry worked together to create amazingly complex and capable satellites. Intelligence gained from these systems proved critical in winning the Cold War.

These satellites' powerful cameras used long rolls of thin plastic light-sensitive film to make photo negatives -- the cameras were not digital like many of today's cameras. Negatives exposed in space came back to earth in film return capsules to be developed and studied.

Satellites on Display

There are three satellites on display: GAMBIT 1 KH-7, GAMBIT 3 KH-8 and HEXAGON KH-9. "KH" refers to the "Keyhole" code name for satellite camera systems. All three used specially-designed film and cameras to take pictures in orbit.

The vehicles on display are among the most important U.S. photo reconnaissance systems used from the 1960s to the 1980s.

No More "Pearl Harbors"

In the late 1950s, little information about nuclear arms was available from the Soviet Union and other communist nations. Communist "closed societies" posed a real -- if unknown -- threat to the U.S. and other democratic nations. Many Americans believed a nuclear attack by the USSR was possible and even probable.

Americans remembered the surprise attack on Pearl Harbor in 1941 and feared a similar attack from the Soviets. The U.S. gained intelligence on early strategic nuclear capabilities by flying camera-equipped aircraft over denied territory, but this tactic proved dangerous and hampered American diplomacy. After the USSR shot down a U-2 reconnaissance aircraft in 1960, overflights of the USSR ended.

Why Did We Need Satellites?

Satellites replaced aircraft overflights after 1960. They gave the U.S. information that could not be gathered in any other way. Finding out about adversaries' strategic missile development drove the early need for reconnaissance satellites, and arms treaty verification became important later in the program.

Passing in space high over their targets behind the communist "Iron Curtain," satellites could not be shot down and risked no harm to crewmen. It was a challenge, however, to create cameras, film, launch vehicles, spacecraft, and other systems needed to make space reconnaissance effective.

Who Made and Used GAMBIT and HEXAGON?

The NRO has overall responsibility for US reconnaissance satellites. The DoD and the CIA formed the NRO in 1961 to manage U.S. space reconnaissance, combining government agency and military efforts.

The NRO traces its roots to the Eisenhower and Kennedy administrations. In the late 1950s, President Dwight Eisenhower urged the DoD to consolidate several national reconnaissance programs. The Kennedy administration authorized the NRO, which added CIA programs to the unifying effort.

After its formation, the NRO assumed management of the first U.S. imagery satellite program. Code-named CORONA, it started as a CIA program with help from the Air Force. The NRO also managed follow-on efforts called ARGON, LANYARD, GAMBIT, and HEXAGON. All these used photographic film and re-entry vehicles to return the exposed film to earth. Later satellites, including those used today, transmit data electronically from space. The NRO continues to manage reconnaissance programs, contributing greatly to national security.

The Air Force Role

The U.S. Air Force has played a key role in space reconnaissance from the beginning. The USAF began working on satellites as early as 1956, and tracked and recovered film-carrying re-entry vehicles from the earliest CORONA missions in 1960 to the last HEXAGON flight in 1986. A special USAF unit collected satellite film in midair near Hawaii and returned it to the mainland for processing.

The USAF also provided launch, tracking, control and range safety services for reconnaissance satellites throughout the entire Cold War, and it continues these activities today. Many NRO satellites have been launched by the USAF from Vandenberg AFB, Calif., into north-south polar orbits necessary for imaging missions. The Air Force Satellite Test Center at Sunnyvale, California, monitored and controlled orbiting satellites.

Value to National Security

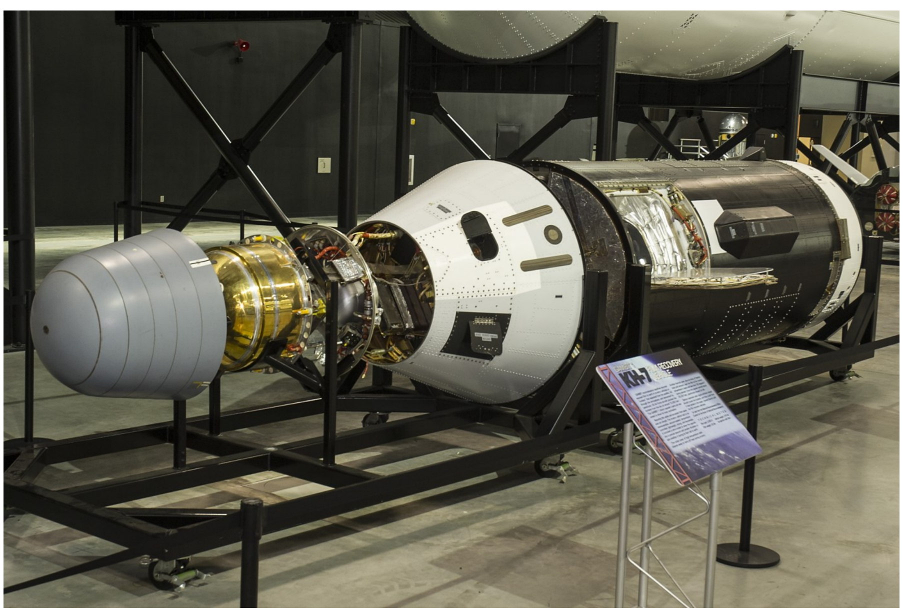
Reconnaissance satellites have played a critical role in maintaining U.S. national security since 1960. They dispelled U.S. fears of a "missile gap," proving the U.S. had not fallen behind the USSR in weapons progress in the 1950s and 1960s. Accurate information from satellites allowed defense officials to act on facts, not speculation.

Over the years, satellites captured images of every new and existing Soviet strategic missile silo. This helped the U.S. confidently verify arms control agreements and track conflicts. The CIA described the value of such knowledge as "virtually immeasurable."

GAMBIT 1 KH-7 Reconnaissance Satellite

The GAMBIT 1 KH-7 satellite was the first American space reconnaissance system to consistently return high-resolution photographs. GAMBIT 1 vehicles flew from 1963-1967 and were the first satellites to feature stereo cameras. Their most significant targets included Soviet missile silos. Of 38 total missions in four years, 36 satellites achieved orbit.

GAMBIT 1 added important new close-up imagery capability to wide-area search satellites already in use. Earlier CORONA satellites took pictures of wide swaths of land to identify items of interest such as airfields and missile sites. The need for close-up surveillance of those targets led to the GAMBIT 1 KH-7. The GAMBIT system included a single film-recovery capsule at the nose and camera gear in the main body of the satellite.



General Electric built both the vehicle housing the KH-7 cameras and the satellite's film recovery capsules, while Eastman Kodak made the cameras and provided the film. Lockheed built the Agena spacecraft that carried the satellite. The Air Force launched GAMBIT 1 KH-7 satellites aboard Atlas-Agena rockets from Vandenberg AFB, California, and provided tracking and control at an Air Force facility in Sunnyvale, California.

Exposed film returned to earth in the film return capsule, which fell through the atmosphere, descended by parachute, and was recovered in midair by specially equipped USAF aircraft near Hawaii.

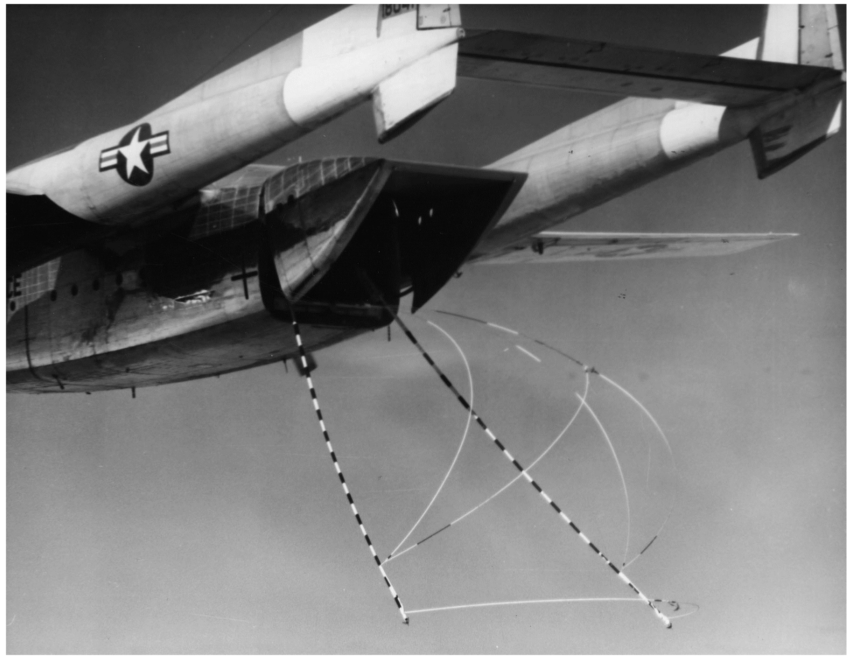
TECHNICAL NOTES:

Altitude: 60-150 nautical miles

Mission duration: 6.6 days average

Camera: KH-7, Eastman Kodak, focal length 77 in, aperture 19.5 in, weight 1,102 lbs.

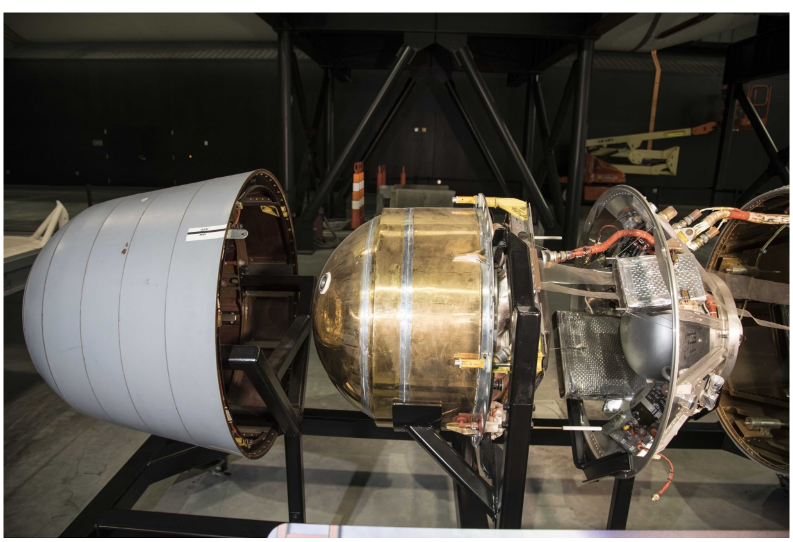
Film: length 3,000 ft., width 9.46 in, weight 52 lbs., 300-600 stereo image pairs per roll



Satellite catching gear deployed from an Air Force C-119J. These aircraft recovered CORONA satellite film capsules beginning in 1960, and later gave way to the faster, more powerful C-130 Hercules aircraft. (U.S. Air Force photo)

GAMBIT 1 KH-7 FILM RECOVERY VEHICLE

GAMBIT reconnaissance satellites returned exposed film to earth in re-entry vehicles or "buckets" that separated from the satellite, fell through the atmosphere, and descended by parachute. US Air Force aircraft plucked the buckets from the sky at around 15,000 feet. This GAMBIT 1 return capsule's parts are separated to show its inner mechanism.



Returning film safely and accurately from space was not simple. The re-entry vehicle had to be maneuverable, vacuum-sealed, temperature-controlled, lightweight, strong, and recoverable. It included a retro-rocket to slow the capsule into a precise descent and smaller thrusters to spin-stabilize it during its fiery fall to earth.

The outer cover of high-temperature resin charred away to carry off heat during re-entry. Another thermal cover, plus an array of thermostats and sensors, kept the film at the correct temperature in space and less than 150 degrees F during descent. Once the capsule reached about 55,000 feet, parachutes slowed its fall.

Battery-operated radio signal emitters helped aircraft locate the buckets, and they could float if they landed in the ocean. General Electric built the film recovery vehicles.

On loan from the National Reconnaissance Office (Center for the Study of National Reconnaissance).

TECHNICAL NOTES:

Film load: 3,000 ft.

Film weight: 52 lbs.

Vehicle weight: 376 lbs. (at ejection with film)

GAMBIT 1 KH-7 image of the Severodvinsk shipyard in the USSR, May 29, 1967

Gambit 3 KH-8 Reconnaissance Satellite

The GAMBIT 3 KH-8 photo reconnaissance satellite improved on the GAMBIT 1 KH-7 by providing much better image resolution. GAMBIT 3's stereoscopic cameras focused on details in small target areas, while other satellites searched wide areas. GAMBIT 3 satellites completed 54 missions from 1966 to 1984.

The most notable improvement from GAMBIT 1 to GAMBIT 3 was the addition of a "roll joint" between the camera module (the forward part on display) and the Agena control vehicle in the rear. This rolling joint made the satellite extremely stable as a photo platform, conserved film, and increased the number of targets photographed. In addition, new super-thin photographic film allowed the vehicle to carry more film.

General Electric built both the GAMBIT 3 vehicle housing cameras and film recovery vehicles, while Eastman Kodak made the KH-8 cameras. Lockheed built the Agena spacecraft. The US Air Force launched GAMBIT 3 KH-8 satellites aboard Titan IIIB rockets from Vandenberg Air Force Base, California, and provided tracking and control at an Air Force facility at Sunnyvale, California.

Film recovery vehicles ejected from the satellites re-entered the atmosphere and then deployed parachutes. Specially equipped USAF aircraft caught the film vehicles in midair near Hawaii.

On loan from the National Reconnaissance Office (Center for the Study of National Reconnaissance).

TECHNICAL NOTES:

Altitude: 65-90 nautical miles

Mission duration: 31 days average

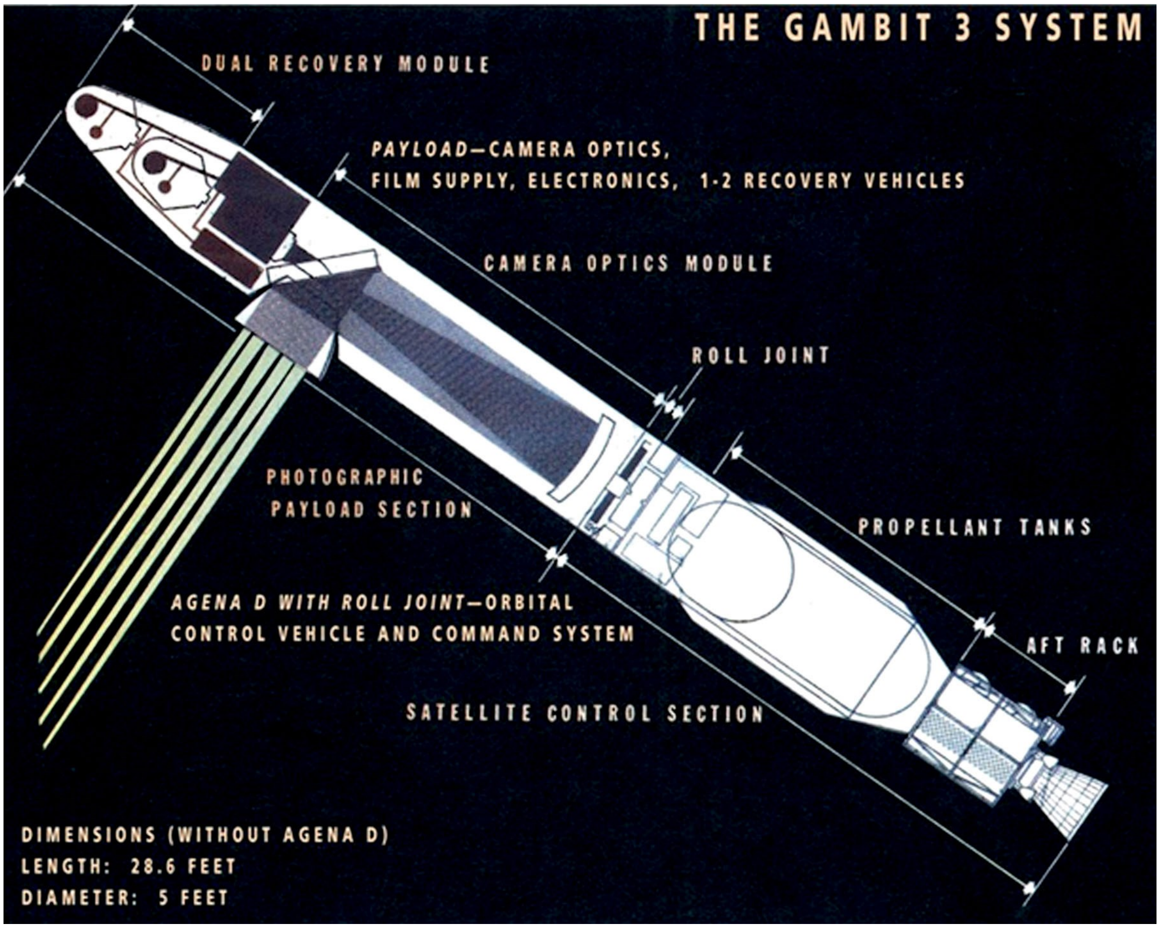
Camera: KH-8, Eastman Kodak, focal length 175 in, aperture 43.5 in

Film: length up to 12,241 ft., widths 5 and 9.5 in

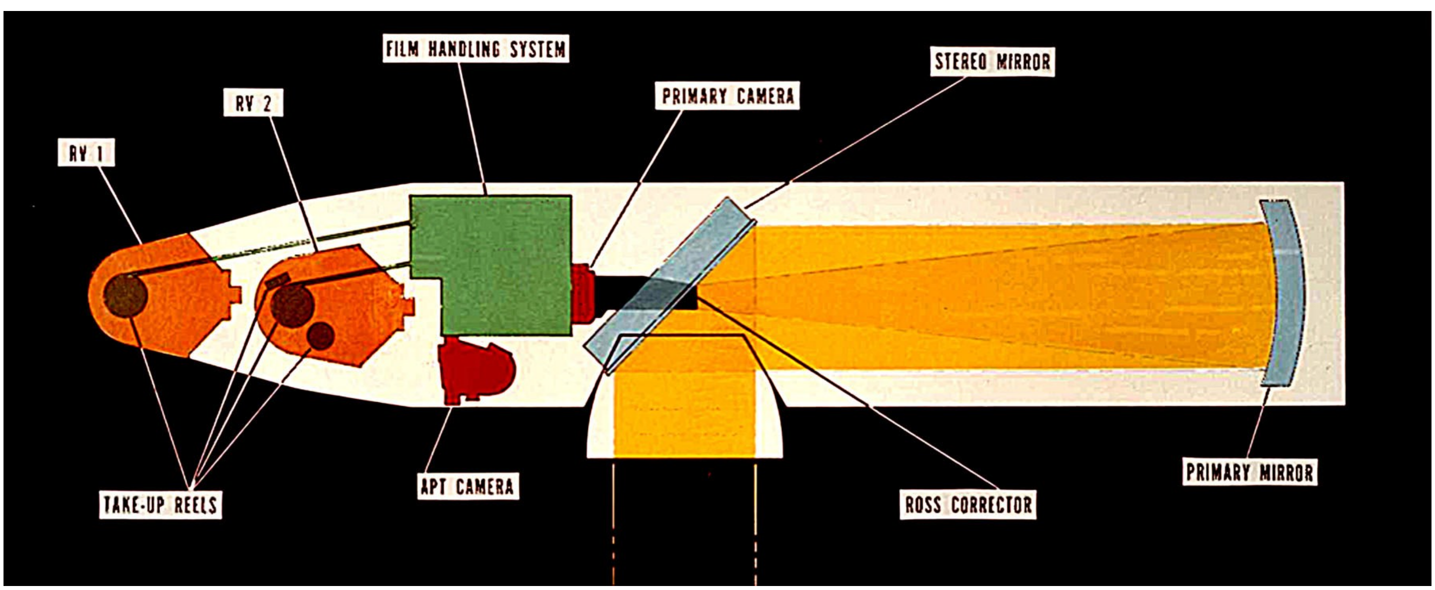
Image resolution: Objects on the ground less than 2 ft. across could be seen on film exposed in orbit

Film recovery capsules: 1 (2 in later missions)

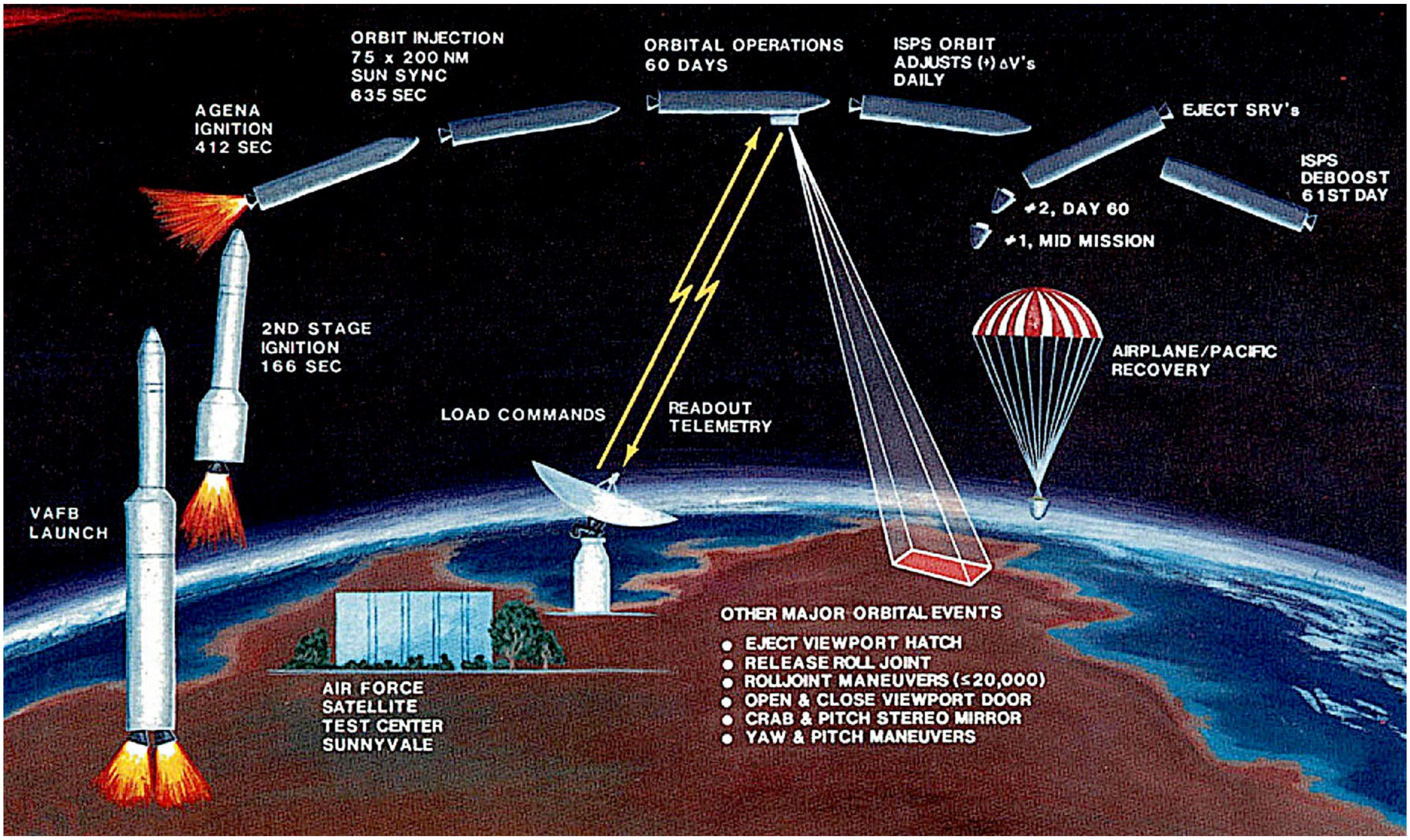
Payload weight: 4,130 lbs. (cameras plus film)



GAMBIT 3 KH-8 schematic showing the folded path camera, roll joint connecting the Agena and payload sections, and dual film return vehicles. (Photo courtesy of National Reconnaissance Office)



This diagram shows how light traveled between mirrors before being corrected for distortion and finally focused on the film plane. (Photo courtesy of National Reconnaissance Office)



GAMBIT 3 KH-8 launch, operation, and recovery sequence. (Photo courtesy of National Reconnaissance Office)

Hexagon KH-9 Reconnaissance Satellite

HEXAGON KH-9 reconnaissance satellites were the largest and last US intelligence satellites to return photographic film to earth. During the Cold War, nineteen HEXAGON missions imaged 877 million square miles of the Earth's surface between 1971-1986.

HEXAGON's main purpose was wide-area search. Analysts pored over HEXAGON's photos of large areas, then focused in on potential threats with close-up surveillance from GAMBIT satellites.

The Lockheed Corporation built the HEXAGON vehicle. Its development included creating a very complex camera and film system. The satellite featured two separate cameras, designated KH-9 and made by the Perkin-Elmer Corporation, working together to produce stereo images. These so-called "optical bar cameras" on the bottom of the satellite spun on their axes, taking overlapping images to form a very large panoramic picture. Objects smaller than 2 feet across could be imaged from around 80-100 miles altitude.

Some missions included a separate mapping camera mounted at the front of the satellite. This camera imaged wider areas to make very accurate maps for war planning and featured its own bucket-like film return vehicle.

The US Air Force launched HEXAGON satellites aboard Titan IIID rockets from Vandenberg AFB, California, and provided tracking and control at an Air Force facility at Sunnyvale, California. USAF aircraft recovered film return vehicles in midair near Hawaii.

On loan from the National Reconnaissance Office (Center for the Study of National Reconnaissance).

TECHNICAL NOTES:

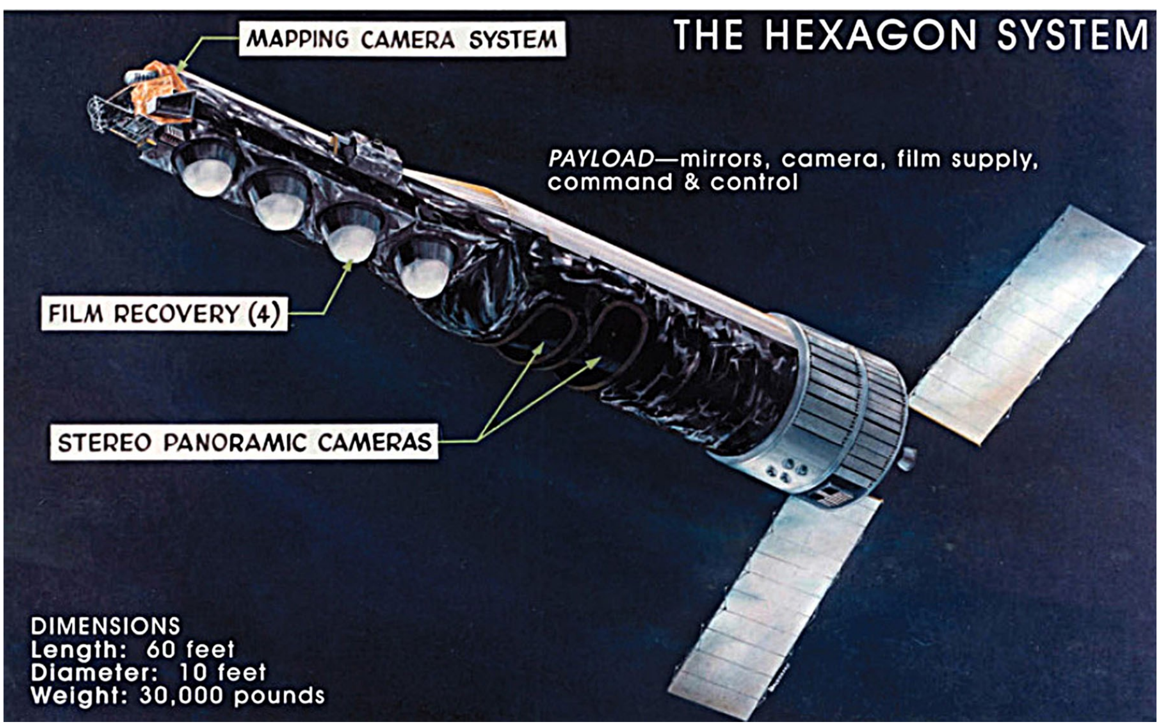
Altitude: 80-370 nautical miles

Mission duration: 124 days average

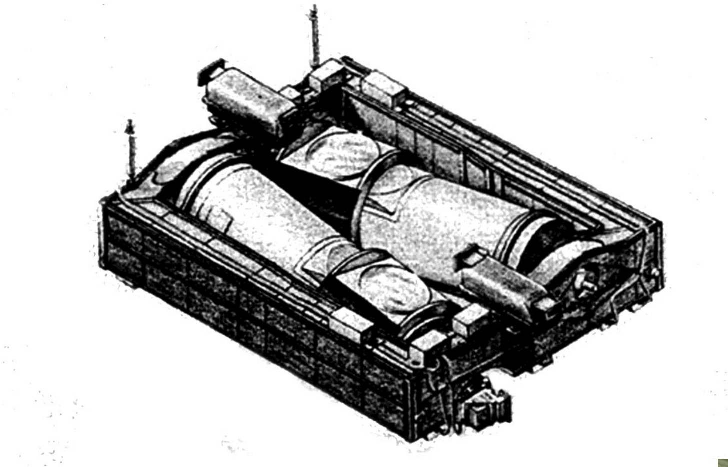
Panoramic cameras: Perkin-Elmer, 60 in focal length f/3.0, aperture 20 in

Mapping camera: Itek, 12-in focal length f/6.0, 9.5 in film, with two Itek 10-in focal length f/2.0, 70mm film cameras for star-tracking position reference

Film: length 320,000 ft. (about 60 miles), width 6.6 in



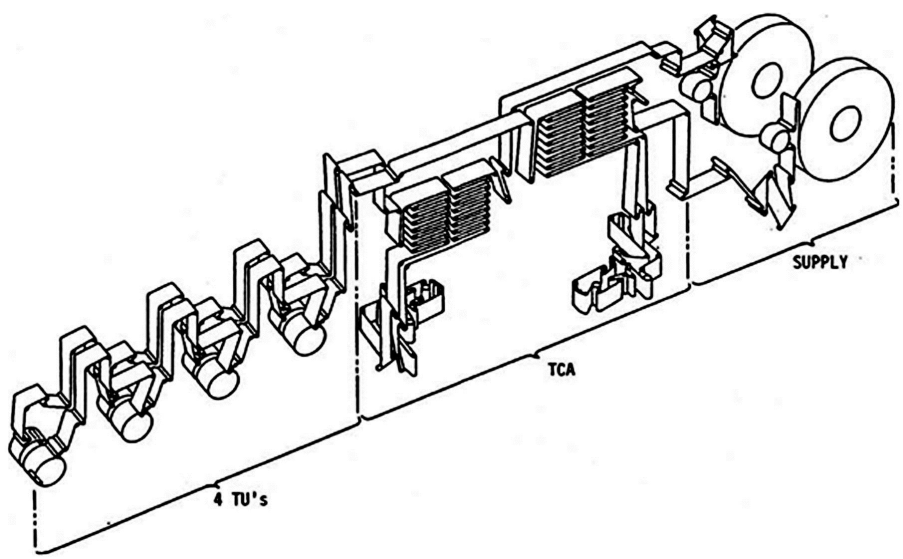
Basic elements of the HEXAGON KH-9, with mapping camera. (Photo courtesy of National Reconnaissance Office)



Drawing showing the side-by-side arrangement of HEXAGON's twin rotating KH-9 panoramic cameras.

(Drawing courtesy of National Reconnaissance Office)

You can see both cameras on the underside of the satellite.



This drawing shows the extremely complex path of HEXAGON KH-9 main camera film. It ran through more than 100 rollers and precision "air bar" assemblies where it floated on a cushion of gas. The feed reels are on the right, and the four return capsules are on the left, with the cameras in the middle. Film moved at up to 200 inches per second inside the airtight, light-tight, pressurized, climate-controlled film path. (Photo courtesy of National Reconnaissance Office)

HEXAGON KH-9 Film Recovery Vehicle

HEXAGON KH-9 reconnaissance satellites featured four recovery vehicles or “buckets” that dropped back to earth from orbit carrying exposed reconnaissance camera film for processing. A mapping camera attached for some missions at the front of the satellite added a fifth, smaller bucket. US Air Force aircraft snatched the parachuting buckets in midair over the Pacific Ocean near Hawaii.

HEXAGON film return buckets had to be maneuverable, vacuum-sealed, temperature-controlled, lightweight, strong, and recoverable. Once ejected from the HEXAGON vehicle, a small retro-rocket slowed the vehicles for atmospheric re-entry, with smaller thrusters providing, and then slowing, a stabilizing spin.

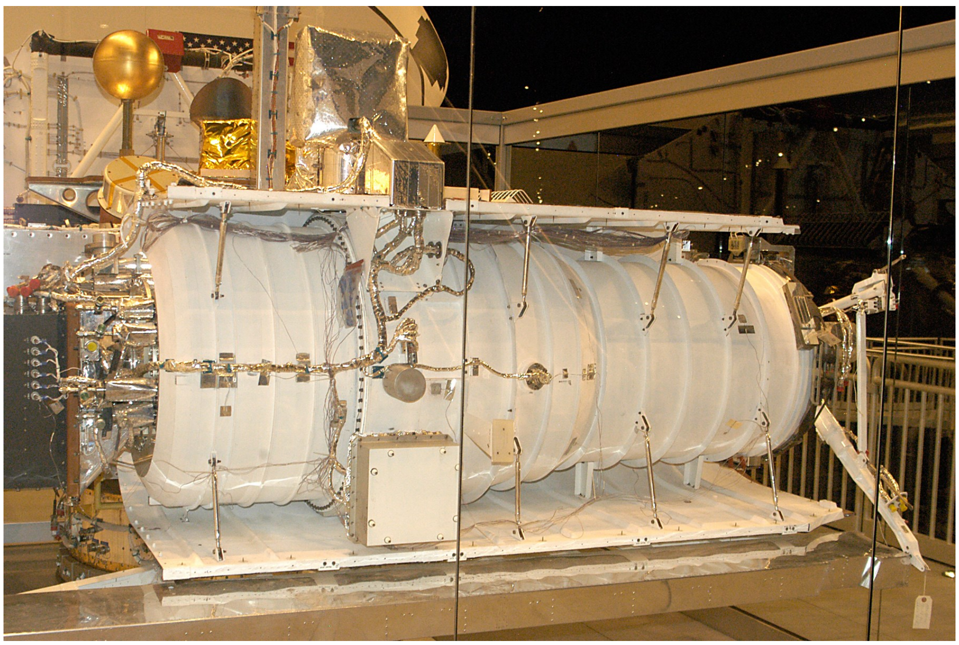
The outer cover of high-temperature resin charred away to carry off heat during re-entry. Another thermal cover, plus an array of thermostats and sensors, kept the film at the correct temperature in space and during descent. Once the vehicle reached about 50,000 feet, parachutes slowed its descent. Battery-operated radio signal emitters helped aircraft locate the buckets, which could float if they landed in the ocean. McDonnell-Douglas built the KH-9’s Mark 8 recovery vehicles, while General Electric made the mapping camera’s smaller Mark V vehicles.

On loan from the National Reconnaissance Office (Center for the Study of National Reconnaissance).

Teal Ruby Experimental Early Warning Sensor

This satellite, known as spacecraft P80-1, carried an experimental infrared telescope code named "Teal Ruby." Designed to detect heat, Teal Ruby was meant to give early warning of enemy aircraft crossing the polar region toward the United States during the Cold War.

The Teal Ruby telescope is inside the white barrel-shaped object facing the forward end of the Space Shuttle exhibit. Along with the telescope, the graphite epoxy barrel houses gyroscopes, cooling equipment, and electronics. In the late 1970s, Teal Ruby featured new technology, now used in digital cameras, enabling it to continuously image large areas for long periods.



TECHNICAL NOTES:

Telescope: Infrared, cryogenically cooled to -375 degrees F, four mirrors, f/3.3, focal length 66 in

Orbit: Intended to be circular, altitude 414 miles (low earth orbit), 72 and later 57 degree inclination from the equator

Weight: P80-1 spacecraft 5,160 lbs., Teal Ruby telescope 61 lbs.

The Teal Ruby telescope aboard P80-1, along with other experiments, was to be launched on a space shuttle in the 1980s. However, the US Air Force cancelled the project due to high costs, technology issues, and complications following the Space Shuttle *Challenger* accident. Instead, spacecraft P80-1 became a test-bed for studying how space equipment ages in storage.

Along with detecting aircraft from space, Teal Ruby had other capabilities. It was also projected to conduct ocean surveillance to target ships, provide missile launch warning, detect other satellites, and see major events on the Earth's surface.

The USAF and the Defense Advanced Research Projects Agency (DARPA) sponsored the Teal Ruby project. Rockwell International Corporation developed the Teal Ruby telescope.

Missiles and Launch Vehicles

Vought ASM-135A Anti-Satellite Missile

The ASM-135A anti-satellite missile (ASAT) was the only U.S. air-launched missile ever to destroy a satellite. In the late 1970s, the U.S. anticipated Soviet development of “killer satellites” that could destroy vital US reconnaissance and communication satellites. The anti-satellite missile countered this threat. Airborne tests with “captive” (not launched) ASAT missiles on modified F-15 fighters began in 1982.

In September 1985, an ASM-135A destroyed a real satellite in a pre-planned test. An F-15A launched the missile at 38,100 feet. Streaking into space, the missile homed in on the U.S. Solwind P78-1 satellite at 345 miles above the Earth, and impacted the one-ton spacecraft at about 15,000 mph.

The Solwind solar observation satellite was operational but several of its instruments had failed. This, along with other political and technical factors, led to its selection as a target for the ASM-135A. This test was the first and only time a U.S. missile destroyed a satellite.

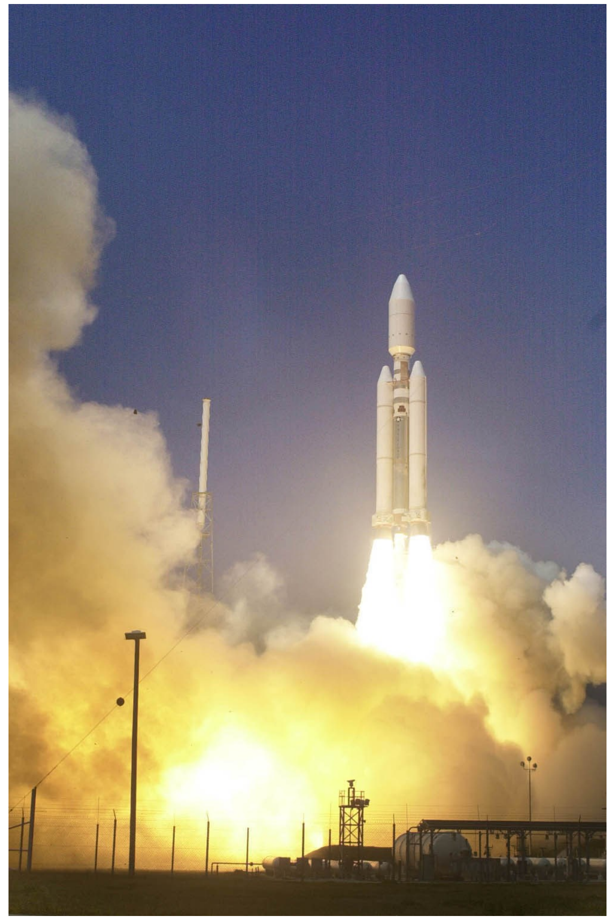
Two solid-rocket stages propelled the missile into space, and a “miniature homing vehicle” (MHV) locked onto the satellite’s infrared image with a telescopic seeker. The MHV spun rapidly for stability and corrected its course with 63 small rocket motors.

Political and public concern about the Cold War arms race extending into space affected the program along with budget and development issues. The U.S. Air Force terminated the ASAT program in 1988. The missile on display is a captive version of the ASM-135A, designated CASM-135A.

TECHNICAL NOTES:

Launch: From F-15A aircraft at 38,100 feet
Target altitude: Approx. 350 miles (low earth orbit)
Maximum speed: 15,000 mph
Guidance: Infrared heat seeking

Lockheed Martin Titan IVB Rocket



The Titan IVB was the U.S. Air Force's largest and most powerful expendable single-use rocket. It was a space launch vehicle used to place satellites into orbit. Titan IVB rockets boosted payloads into low earth orbit, polar orbit, or geosynchronous (stationary) orbit from either Cape Canaveral, Florida, or Vandenberg Air Force Base, California.

Although the Titan IVB was not a missile (a weapon), it was developed from a long line of missiles and launch vehicles based on the original Titan Intercontinental Ballistic Missile (ICBM). First launched in 1959, the Titan family of boosters served for nearly 50 years putting satellites and astronauts into orbit. Titan IVB flew from 1997 to 2005 with all 17 of its launches successful.

Titan IVB rockets carried several notable payloads, including classified National Reconnaissance Office satellites, early warning satellites and meteorological satellites. In 1997 a Titan IVB also launched NASA's Cassini-Huygens spacecraft to study Saturn and its moon Titan.

The front end of the rocket is the payload fairing. It protected satellites on the way through the atmosphere to orbit, then broke away to release the payload. Fairings varied in length according to the size of the satellite. The rocket on display has an 86-foot fairing, the longest one used. Titan IVB payloads could be as heavy as 23.9 tons, about the size and weight of a large tour bus.

TECHNICAL NOTES:

Length: 204 feet
Weight: 2.2 million lbs. maximum liftoff weight
Lift capability: 47,800 lbs. (low-earth orbit), 12,700 lbs. (geosynchronous orbit using Centaur Upper Stage), 38,800 lbs. (low-earth polar orbit), 5,250 lbs. (geosynchronous orbit using Inertial Upper Stage)
Engines: Two-stage liquid-fuel core vehicle with two solid rocket boosters. Stage 1, LR87 engine of 548,000 lbs. thrust; stage 2, LR91 engine of 105,000 lbs. thrust. Two solid rocket motors of 1.5 million lbs. thrust each.

Additional missiles and related exhibits are located in the Missile Gallery.

Engines

Rocketdyne LR79

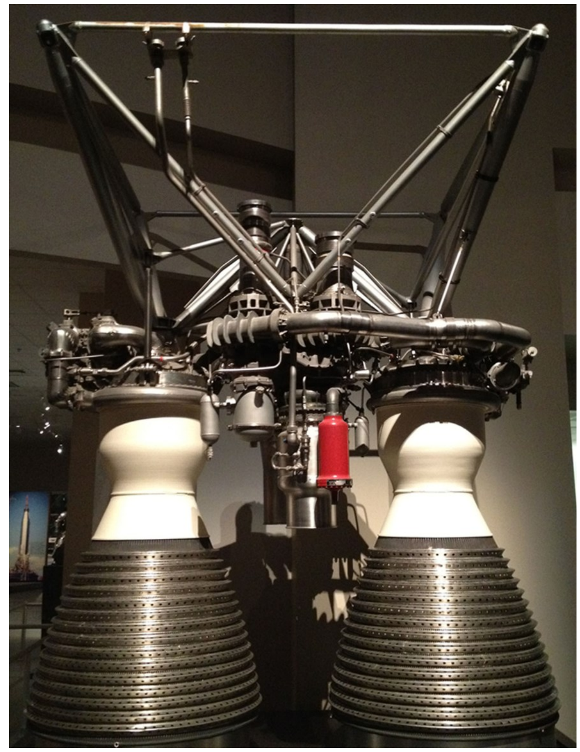
The LR79 rocket engine was a reliable workhorse for U.S. Air Force space and missile launches between 1958 and 1980. Variants of this liquid-fueled engine powered Jupiter and Thor Intermediate Range Ballistic Missiles (IRBMs), Juno II satellite boosters, and Saturn I and IB rockets used in the Apollo, Skylab, and Apollo-Soyuz programs. The LR79 was also known by its civilian designation S-3/S-3D.

Rocketdyne developed the engine in 1955-56 for the U.S. Army. In 1956, Jupiter became an important Air Force missile when the USAF gained responsibility for all ballistic missiles with ranges of more than 200 miles. An LR79 engine powered a Jupiter on the first successful American IRBM test flight on May 3, 1957. In 1959, a Jupiter rocket took two monkeys named Able and Baker on a 16-minute sub-orbital ride to an altitude of 300 miles, a prelude to human spaceflight.

A Rocketdyne LR79 (S-3D) engine ignites during a Jupiter test launch at Cape Canaveral, Florida, in 1960. Note the coating of frost around the missile's center, caused by cold liquid oxygen. (U.S. Air Force photo)

TECHNICAL NOTES:
Thrust: 150,000–205,000 lbs. (depending on model)
Weight: 1,417–2,003 lbs. (depending on model)
Turbopump speed: 3,950–6,717 rpm (depending on model)
Propellants: RP-1 (kerosene) and liquid oxygen
Propellant flow: About 3,400 gallons liquid oxygen and 2,100 gallons kerosene per minute (depending on model)

Aerojet-General LR87



The LR87 is a liquid-fueled rocket engine first used on Titan Intercontinental Ballistic Missiles (ICBMs). LR87 variants also powered the first stages of Titan space boosters in the Gemini manned spaceflight program and various Titan space launch vehicles. Though this powerful engine is in reality two engines working together, it is considered a single unit. The LR87 first flew in 1959.

The pipes around the top of the engine's two parts deliver fuel and oxidizer to high-speed turbopumps. The pumps then push these propellants to the bell-shaped thrust chambers, where the liquid mix becomes a mist and ignites, creating thrust. The machinery between the thrust chambers generates hot gas to drive the turbopumps.

LR87s came in several different models and used a variety of propellants. Early production LR87s used liquid oxygen and kerosene propellants. Later models used hypergolic fuels, which are liquids that ignite when mixed together. Hypergolics have an advantage over other propellants because they can be stored in the rocket at room temperature for long periods of time, making launches faster and simpler.

The LR87 is a fixed thrust engine -- it cannot be throttled, and it is not restartable in flight. Both of the engine's thrust chambers can gimbal, or tilt slightly, for steering.

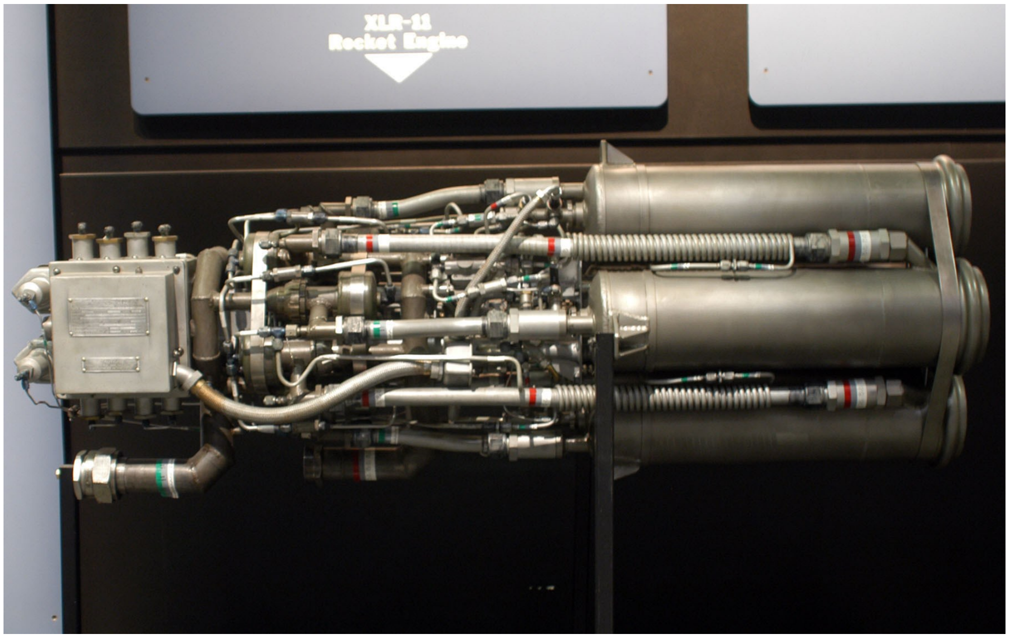
TECHNICAL NOTES:

Burn time: About 165-200 seconds depending on engine model and propellants
Propellants burned: 25,500 gal (170 gal per second)
Turbopump speed: 24,000 rpm
Thrust: 430,000 lbs.

Reaction Motors XLR11 Rocket

The XLR11 was the first liquid-fuel rocket engine developed in the United States for use on airplanes, and it had a long career powering important research aircraft. An XLR11 engine powered the first airplane to break the speed of sound, the Bell X-1, in 1947, and also powered other X-1 models. XLR11s also flew in the X-24A and X-24B lifting bodies and other vehicles including the record-breaking X-15s, which used two XLR11 engines mounted together during their early flights.

The XLR11, also known early in its career as the LR11, delivered a total of 5,900 pounds of thrust. It featured the ability to stop and restart its four individual chambers, but the engine was only "on-off" and not throttleable like the later XLR99 on display nearby. The engine's propellants were liquid oxygen and a mix of water and ethyl alcohol. A pressurized system delivered propellants to the engine in early versions; later versions used turbopumps. Like later engines, the XLR11 circulated fuel around its thrust chambers to cool them before the fuel was burned.



TECHNICAL NOTES:

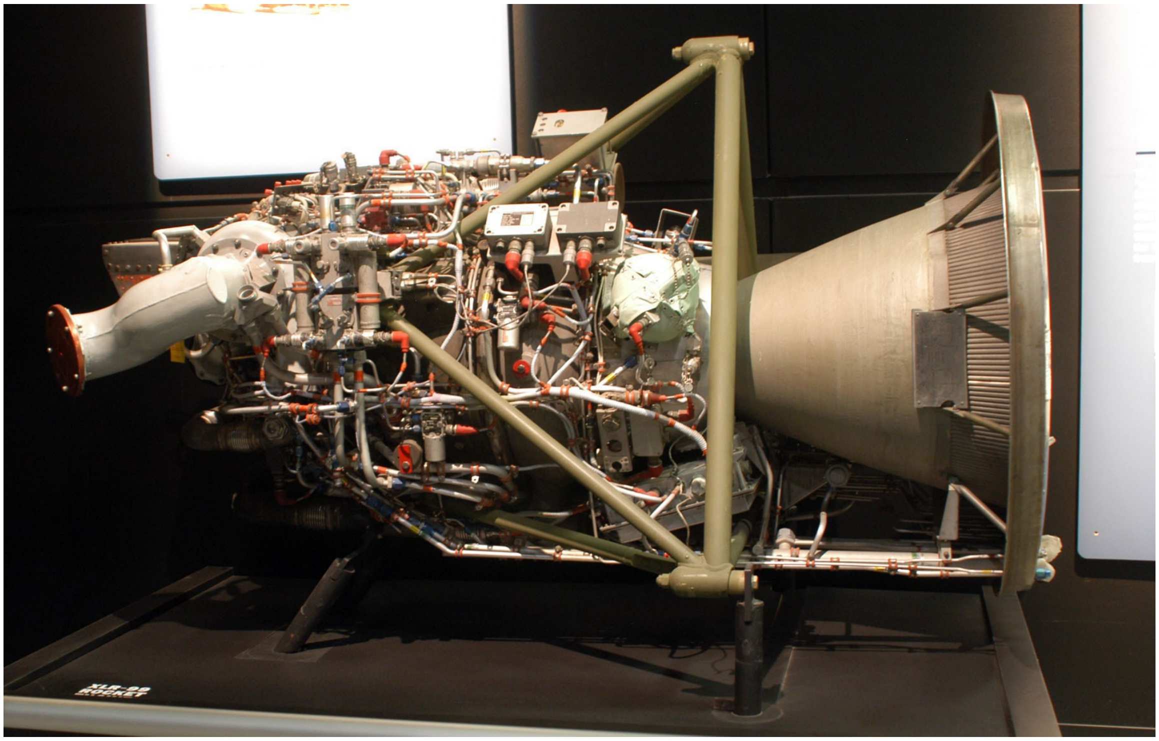
Thrust: 5,900 lbs. (1,475 lbs. in each of four chambers)
Propellants: Ethyl alcohol and water fuel and liquid oxygen oxidizer
Weight: 345 lbs. including turbopump

Reaction Motors XLR99 Rocket

The XLR99 powered the record-breaking X-15 on its fastest flights at nearly seven times the speed of sound. It was the first large, throttleable, restartable liquid propellant rocket engine to be used in a piloted vehicle. The engine was used only in the X-15 program, which rocketed humans to the edge of space. The X-15A-2 in this gallery has an XLR99 engine.

Developed and built by the Reaction Motors Division of Thiokol Chemical Corp., the XLR99 could deliver more than 57,000 pounds of thrust. The engine used liquid oxygen and anhydrous ammonia propellants fed into the engine by turbopumps at a flow rate of more than 10,000 pounds per minute.

The XLR99 engine had an operating life of one hour, after which it could be overhauled and used again, though operating times twice that long were demonstrated in tests. The XLR99 was theoretically capable of between twenty and forty flights before overhaul. The basic X-15 carried propellants for about 83 seconds of full-power flight, and the X-15A-2 carried enough in its twin orange external tanks for more than 150 seconds of full-power flight.



Like other large liquid fueled rocket engines, the walls of the XLR99's thrust chamber included hollow tubing so that fuel could be routed through the tubes to cool the chamber walls before being burned in the engine.

TECHNICAL NOTES:

Thrust: 50,000 lbs. at sea level; 57,000 lbs. at 45,000 ft.; 57,850 lbs. at 100,000 feet
Propellants: Liquid anhydrous ammonia fuel and liquid oxygen oxidizer
Weight: 915 lbs. including turbopump

This guide features some of the space-related artifacts and exhibits at the National Museum of the USAF. Visit the Museum's web site at www.nationalmuseum.af.mil for a complete listing.

Suggested Resources

Videos available for loan through the National Museum of the USAF Education Division

For high school and adult audiences from The Wings and Things Guest Lecture Series:

http://www.nationalmuseum.af.mil/Portals/7/documents/education/guest_lecture_video_loan_program.pdf

V007 ***Traveling to Space: Then and Now*** by Lieutenant General Thomas P. Stafford, USAF (Ret)

Before becoming commander of the Air Force Flight Test Center at Edwards Air Force Base, General Stafford was himself a fighter pilot, a test pilot, and eventually an astronaut. As part of the Gemini and Apollo projects, he made several space flights and was the commander of the Apollo-Soyez Test Project mission from July 15-24, 1975. Stafford offers a unique personal perspective on the space program from the vantage point of both astronaut and program manager.

V023 **2001: A Space Station Odyssey** by Dr. Thomas Jones

Dr. Jones focuses on his crew's STS-98 mission to the International Space Station (ISS) where Atlantis delivered the U.S. Laboratory Module, Destiny, to the station. He presents his personal impressions of space flight and space walking, and discusses our prospects for future human expeditions beyond Earth's orbit.

V193 **Life at the International Space Station** by Colonel Gregory H. Johnson, USAF

Colonel Johnson, NASA astronaut and Air Force colonel, discusses his time as the pilot of STS-123 Endeavor from March 11-26, 2008. It was the 25th Shuttle/Station assembly mission, and was accomplished in approximately sixteen days and 250 orbits around the Earth. He was assigned to NASA's Space Shuttle Branch in 2001, where he held different positions to support earlier STS crews and to develop various plans, procedures and contingency scenarios.

V235 **The Secret World of Space Reconnaissance: Why the U. S. Air Force and the Central Intelligence Agency Established the Invisible National Reconnaissance Office, and How They Developed the Gambit and Hexagon Photoreconnaissance Satellites** by Dr. Robert A. McDonald and Dr. James D Outzen

Dr. McDonald and Dr. Outzen, two CIA officers assigned to the National Reconnaissance Office (NRO) discuss the secret world of space reconnaissance and the partnering of the U. S. Air Force with the previously highly-classified intelligence agency, the NRO. McDonald explains the role that the Air Force played in the creation and operation of the formerly-classified NRO. Outzen discusses the recently-declassified Gambit and Hexagon NRO satellite photoreconnaissance programs as case study exemplars of the overall partnership.

V236 **The Air Force in Space—and on the Moon: The Flights of Apollo 9 and Apollo 15** by Colonel David R. Scott, USAF (Ret)

Colonel Scott graduated near the top of his class at West Point in 1954, served as an Air Force fighter pilot until 1960, earned two graduate degrees at MIT in 1962, graduated from Air Force Experimental Test Pilot School in 1963 and from the Air Force Aerospace Research Pilot School in 1964—but he was just getting started! Scott was selected in the third group of NASA astronauts, and he flew three space missions. The first was in March 1966: Gemini VIII, the first docking in space; the second was in March 1969: Apollo 9, the first test flight of all spacecraft and flight operations for the Apollo lunar missions (except landing); the third was in July 1971: he was the commander for Apollo 15 (lunar landing mission).

For School Audiences:

http://www.nationalmuseum.af.mil/Education/AVLoan.aspx

People and Space
V092
Grades K-5—41 minutes
Four segments show what it takes to put astronauts into space and to keep them there as they live and work: The Space Shuttle, Support Staff; Zero Gravity and Living in Space. [From the Discovery Channel]

The Dream is Alive
V078
Grades 3-12—37 minutes
Gives you a window seat on the space shuttle. Share the astronauts' experience of working, eating, and sleeping in microgravity. Witness an exciting satellite repair -- proof that we can work in space -- and the historic walk in space by an American woman. [IMAX film]

Blue Planet
V080
Grades 6-12—42 minutes
Filmed by astronauts from five space shuttle missions, Blue Planet dramatically reveals the forces affecting Earth's fragile ecological balance: hurricanes, volcanoes, earthquakes, and ultimately -- humankind. [IMAX film]

Destiny in Space
V081
Grades 6-12—40 minutes
A tribute to the continuing exploration of the solar system and the universe beyond. Viewers are part of the space shuttle crew, deploying and repairing the Hubble Space Telescope. Travel millions of miles beyond Earth, finding evidence of new planets. Narrated by Leonard Nimoy. [IMAX film]

Eyes in the Sky
V093
Grades 6-12—51 minutes
From predicting the weather to orienting drivers on the ground, satellites circle Earth carrying the most advanced information-processing technology in the world. What began as a Cold War surveillance tool now has a multitude of uses. [From the Discovery Channel]

He Conquered Space
V096
Grades 6-12—51 minutes
Look into the life of Wernher von Braun, the most important figure in the American space program. From his boyhood sketches to his design of Hitler's V-2 rocket and to the creation of the rocket that shot American astronauts to the moon, von Braun's genius inspired and enabled the exploration of outer space. [From the Discovery Channel]

Pioneers in Space

V099

Grades 6-12—50 minutes

Mike Wallace narrates this documentary about our Mercury astronauts and the Cold War space race. From Alan Shepard's sub-orbital journey in 1961 to John Glenn's latest mission in 1998, this video depicts the wondrous development of space flight in America as well as in the Soviet Union. [From the History Channel]

The Space Shuttle

V094

Grades 6-12—48 minutes

Divided into four segments; explores scientists' most amazing spacecraft. Learn about the history of the space shuttle program and how it fulfilled a decade of dreams for NASA engineers. See how the shuttle is put together in the Vehicle Assembly Building at Kennedy Space Center in Florida. Then, train with the shuttle astronauts as they learn to cope with microgravity and the rigors of space. [From the Discovery Channel]

Understanding Space Travel

V097

Grades 6-12—52 minutes

Off we go into the wild blue yonder, spending billions of dollars to reach farther and farther into space. Probe space exploration and the complex physics behind rocket science, thrust, and gravity. [From the Discovery Channel]

History of Space Flight-Reaching For The Stars

V052

Grades 4-12—60 minutes

Narrated by astronaut Alan Shepard, this production is one of the most complete collections of historical footage, computer animation, and rare images ever assembled regarding space flight. [Holiday Space & Science series]

NATIONAL MUSEUM
OF THE UNITED STATES AIR FORCE™